Electronic Version
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Claims

[c1] 1. A method for injecting virtual flaw signals into a nondestructive test system, comprising the steps for:

moving a test probe over a test piece by an inspector;

providing an excitation signal from the nondestructive test system to the test probe and a virtual flaw injection circuit;

determining virtual flaw parameter signals from test probe position signals and a stored virtual flaw map for the test piece;

sending the virtual flaw parameter signals and an output signal from the test probe to the virtual flaw injection circuit;

processing the excitation signal and the test probe output signal using the virtual flaw parameter signals for generating a virtual flaw response signal by the virtual flaw injection circuit;

transmitting the virtual flaw response signal to a test probe input of the nondestructive test system; and

displaying actual and virtual flaws to the inspector from the nondestructive test system.

[c2] 2. The method of claim 1, wherein the step for determining virtual flaw parameter signals further comprises the steps for:

reading the test probe position signals for indicating test probe positions relative to a test piece;

reading test probe liftoff measurement signals for indicating test probe liftoff from the test piece;

reading a virtual flaw map for the test piece stored in a memory for determining uncorrected virtual flaw parameter signals based on the test probe position signals; and

applying a liftoff correction based on the test probe liftoff measurement signals to the uncorrected virtual flaw parameter signals for determining corrected virtual flaw parameter signals.

[c3] 3. The method of claim 1, wherein the step for processing further comprises the steps for:

modulating an amplitude of the excitation signal by the virtual flaw parameter signals;

shifting a phase of the amplitude modulated excitation signal by the virtual flaw parameter signals; and

summing the amplitude modulated and phase shifted excitation signal with the test probe output signal for generating a virtual flaw response signal by the virtual flaw injection circuit.

[c4] 4. The method of claim 3, wherein the step for modulating an amplitude comprises modulating an amplitude of the excitation signal by virtual flaw gain parameter signals and the step for shifting a phase comprises shifting the phase of the excitation signal by virtual flaw phase shift parameter signals.

[c5] 5. The method of claim 4, wherein the step for modulating the amplitude of the excitation signal comprises the steps for:

connecting the excitation signal to the input of a variable gain amplifier;

controlling the gain of the variable gain amplifier by the virtual flaw gain parameter signal; and

providing an amplitude modulated excitation signal at the output of the variable gain amplifier.

[c6] 6. The method of claim 4, wherein the step for shifting the phase of the amplitude modulated excitation signal comprises the steps for:

connecting the amplitude modulated excitation signal to the input of a variable phase shifter;

controlling the phase shift of the variable phase shifter by the virtual flaw phase shift parameter signal; and

providing an amplitude modulated and phase shifted excitation signal at the output of the variable phase shifter.

[c7] 7. The method of claim 1, further comprising the step for basing the nondestructive test system on eddy current technology.

[c8] 8. A method for injecting virtual flaw signals into a nondestructive test system, comprising the steps for:

connecting a flaw signal injection circuit between a nondestructive test instrument and a nondestructive test probe;

receiving an excitation signal, a test probe output signal and virtual flaw parameter signals by the flaw signal injection circuit while moving a test probe over a test piece by an inspector;

modulating an amplitude and shifting a phase of the excitation signal under control of the virtual flaw parameter signals in the flaw signal injection circuit;

summing the amplitude modulated and phase shifted excitation signal with the test probe output signal for generating a virtual flaw response signal by the virtual flaw injection circuit; and

sending the virtual flaw response signal from the virtual flaw injection circuit to a test probe input of the nondestructive test instrument for display of virtual and actual flaws to an inspector.

[c9] 9. The method of claim 8, wherein the step for receiving virtual flaw parameter signals further comprises receiving virtual flaw parameters signals determined by the steps for:

reading test probe position signals for indicating test probe positions relative to a test piece;

reading test probe liftoff measurement signals for indicating test probe liftoff from the test piece;

reading a virtual flaw map for the test piece stored in a memory for determining uncorrected virtual flaw parameter signals based on the test probe position signals; and

applying liftoff correction based on the test probe liftoff measurement signals to the uncorrected virtual flaw parameter signals for determining corrected virtual flaw parameter signals.

[c10] 10. The method of claim 8, wherein the step for modulating an amplitude comprises modulating an amplitude of the excitation signal by virtual flaw gain parameter signals and the step for shifting a phase comprises shifting the phase of the excitation signal by virtual flaw phase shift parameter signals.

[c11] 11. The method of claim 10, wherein the step for modulating the amplitude of the excitation signal comprises the steps for:

connecting the excitation signal to the input of a variable gain amplifier;

controlling the gain of the variable gain amplifier by the virtual flaw gain parameter signal; and

providing an amplitude modulated excitation signal at the output of the variable gain amplifier.

[c12] 12. The method of claim 10, wherein the step for modulating the amplitude of the excitation signal comprises the steps for:

connecting the excitation signal to a high terminal of an input digital potentiometer;

connecting a wiper terminal of the input digital potentiometer to a noninverting input of a differential amplifier;

connecting a wiper terminal of a feedback digital potentiometer to an inverting input of the differential amplifier;

connecting an output of the differential amplifier to a high terminal of the feedback digital potentiometer;

connecting a low terminal of the input digital potentiometer and the feedback digital potentiometer to ground reference potential;

connecting the virtual flaw gain parameter signal to a control input of the input digital potentiometer and a control input of the feedback digital potentiometer; and

providing an amplitude modulated excitation signal at the output of the differential amplifier.

[c13] 13. The method of claim 10, wherein the step for shifting the phase of the amplitude modulated excitation signal comprises the steps for:

connecting the amplitude modulated excitation signal to the input of a variable phase shifter;

controlling the phase shift of the variable phase shifter by the virtual flaw phase shift parameter signal; and

providing an amplitude modulated and phase shifted excitation signal at the output of the variable phase shifter.

[c14] 14. The method of claim 10, wherein the step for shifting the phase of the amplitude modulated excitation signal comprises the steps for:

connecting three identical phase shift circuits in a cascade configuration, including the steps for:

connecting an input of a first phase shift circuit to the amplitude modulated excitation signal;

connecting an output of the first phase shift circuit to an input of a second phase shift circuit;

connecting an output of the second phase shift circuit to an input of a third phase shift circuit;

providing an output of the third phase shift circuit as the amplitude modulated and phase shifted excitation signal;

shifting the phase of a signal at an input of each phase shift circuit, including the steps for:

connecting the input signal of each phase shift circuit to a first terminal of an input resistor and a first terminal of an input capacitor;

connecting a second terminal of the input capacitor to a

noninverting input of a differential amplifier and a high terminal of a digital potentiometer;

connecting a wiper terminal and a low terminal of the digital potentiometer to a ground reference potential;

connecting a second terminal of the input resistor to a first terminal of a feedback resistor and an inverting input of the differential amplifier;

connecting a second terminal of the feedback resistor to an output of the differential amplifier, the output of the differential amplifier providing an output of the phase shift circuit; and

connecting the virtual flaw phase shift parameter signal to a control input of the input digital potentiometer for varying a phase shift of the phase shift circuit.

[c15] 15. The method of claim 14, wherein the step for shifting the phase of a signal at an input of each phase shift circuit comprises shifting of the input signal between 0 and 120 degrees as represented by the phase shift circuit output signal.

[c16] 16. The method of claim 8, further comprising the step for deriving the virtual flaw map from the group consisting of a model and premeasured flaws.

[c17] 17. The method of claim 8, wherein the nondestructive test instrument and a nondestructive test probe are based on eddy current technology.

[c18] 18. The method of claim 8, further comprising selecting a test probe from the group consisting of a single element probe, a dual element probe and

a triple element probe.

[c19] 19. A system for injecting virtual flaw signals into a nondestructive test system, comprising:

means for moving a test probe over a test piece by an inspector;

means for providing an excitation signal from the nondestructive test system to the test probe and a virtual flaw injection circuit;

means for determining virtual flaw parameter signals from probe test position signals and a stored virtual flaw map for the test piece;

means for sending the virtual flaw parameter signals and an output signal from the test probe to the virtual flaw injection circuit;

means for processing the excitation signal and the test probe output signal using the virtual flaw parameter signals for generating a virtual flaw response signal by the virtual flaw injection circuit;

means for transmitting the virtual flaw response signal to a test probe input of the nondestructive test system; and

means for displaying actual and virtual flaws to the inspector from the nondestructive test system.

[c20] 20. The system of claim 19, wherein the means for determining virtual flaw parameter signals further comprises:

means for reading test probe position signals for indicating test probe positions relative to a test piece;

means for reading test probe liftoff measurement signals for indicating test probe liftoff from the test piece;

means for reading a virtual flaw map for the test piece stored in a memory for determining uncorrected virtual flaw parameter signals

based on the test probe position signals; and

means for applying a liftoff correction based on the test probe liftoff measurement signals to the uncorrected virtual flaw parameter signals for determining corrected virtual flaw parameter signals.

[c21] 21. The system of claim 19, wherein the means for processing further comprises:

means for modulating an amplitude of the excitation signal by the virtual flaw parameter signals;

means for shifting a phase of the amplitude modulated excitation signal by the virtual flaw parameter signals; and

means for summing the amplitude modulated and phase shifted excitation signal with the test probe output signal for generating a virtual flaw response signal by the virtual flaw injection circuit.

[c22] 22. The system of claim 21, wherein the means for modulating an amplitude comprises means for modulating an amplitude of the excitation signal by virtual flaw gain parameter signals and the means for shifting a phase comprises means for shifting the phase of the excitation signal by virtual flaw phase shift parameter signals.

[c23] 23. The system of claim 22, wherein the means for modulating the amplitude of the excitation signal comprises:

means for connecting the excitation signal to the input of a variable gain amplifier;

means for controlling the gain of the variable gain amplifier by the virtual flaw gain parameter signal; and

means for providing an amplitude modulated excitation signal at the output of the variable gain amplifier.

[c24] 24. The system of claim 22, wherein the means for shifting the phase of the amplitude modulated excitation signal comprises the steps for:

the amplitude modulated excitation signal connected to the input of a variable phase shifter;

the phase shift of the variable phase shifter controlled by the virtual flaw phase shift parameter signal; and

an amplitude modulated and phase shifted excitation signal provided at the output of the variable phase shifter.

[c25] 25. The system of claim 19, further comprising the nondestructive test system based on eddy current technology.

[c26] 26. A system for injecting virtual flaw signals into a nondestructive test system, comprising:

a flaw signal injection circuit connected between a nondestructive test instrument and a nondestructive test probe;

an excitation signal, a test probe output signal and virtual flaw parameter signals received by the flaw signal injection circuit while moving a test probe over a test piece by an operator;

an amplitude and a phase shift of the excitation signal being controlled by the virtual flaw parameter signals in the flaw signal injection circuit;

the amplitude modulated and phase shifted excitation signal being summed with the test probe output signal for generating a virtual

flaw response signal by the virtual flaw injection circuit; and

the virtual flaw response signal being sent from the virtual flaw injection circuit to a test probe input of the nondestructive test instrument for display of virtual and actual flaws to an inspector.

[c27] 27. The system of claim 26, wherein the virtual flaw parameter signals further comprises virtual flaw parameters signals determined by:

test probe position signals for indicating test probe positions relative to a test piece;

test probe liftoff measurement signals for indicating test probe liftoff from the test piece;

a virtual flaw map for the test piece stored in a memory for determining uncorrected virtual flaw parameter signals based on the test probe position signals; and

liftoff correction based on the test probe liftoff measurement signals to the uncorrected virtual flaw parameter signals for determining corrected virtual flaw parameter signals.

[c28] 28. The system of claim 26, wherein the means for modulating an amplitude comprises means for modulating an amplitude of the excitation signal by virtual flaw gain parameter signals and the means for shifting a phase comprises means for shifting the phase of the excitation signal by virtual flaw phase shift parameter signals.

[c29] 29. The system of claim 28, wherein the means for modulating the amplitude of the excitation signal comprises:

means for connecting the excitation signal to the input of a variable

gain amplifier;

means for controlling the gain of the variable gain amplifier by the virtual flaw gain parameter signal; and

means for providing an amplitude modulated excitation signal at the output of the variable gain amplifier.

[c30] 30. The system of claim 28, wherein the means for modulating the amplitude of the excitation signal comprises:

the excitation signal connected to a high terminal of an input digital potentiometer;

a wiper terminal of the input digital potentiometer connected to a noninverting input of a differential amplifier;

a wiper terminal of a feedback digital potentiometer connected to an inverting input of the differential amplifier;

an output of the differential amplifier connected to a high terminal of the feedback digital potentiometer;

a low terminal of the input digital potentiometer and the feedback digital potentiometer connected to ground reference potential;

the virtual flaw gain parameter signal connected to a control input of the input digital potentiometer and a control input of the feedback digital potentiometer; and

an amplitude modulated excitation signal provided at the output of the differential amplifier.

[c31] 31. The system of claim 28, wherein the means for shifting the phase of the amplitude modulated excitation signal comprises the steps for:

the amplitude modulated excitation signal connected to the input of

a variable phase shifter;

the phase shift of the variable phase shifter controlled by the virtual flaw phase shift parameter signal; and

an amplitude modulated and phase shifted excitation signal provided at the output of the variable phase shifter.

[c32] 32. The system of claim 28, wherein the means for shifting the phase of the amplitude modulated excitation signal comprises:

three identical phase shift circuits connected in a cascade configuration, including:

an input of a first phase shift circuit connected to the amplitude modulated excitation signal;

an output of the first phase shift circuit connected to an input of a second phase shift circuit;

an output of the second phase shift circuit connected to an input of a third phase shift circuit;

an output of the third phase shift circuit provided as the amplitude modulated and phase shifted excitation signal;

each phase shift circuit including:

the input signal of each phase shift circuit connected to a first terminal of an input resistor and a first terminal of an input capacitor;

a second terminal of the input capacitor connected to a noninverting input of a differential amplifier and a high terminal of a digital potentiometer;

a wiper terminal and a low terminal of the digital potentiometer connected to a ground reference potential;

a second terminal of the input resistor connected to a first terminal of a feedback resistor and an inverting input of the differential amplifier;

a second terminal of the feedback resistor connected to an output of the differential amplifier, the output of the differential amplifier providing an output of the phase shift circuit; and

the virtual flaw phase shift parameter signal connected to a control input of the input digital potentiometer for varying a phase shift of the phase shift circuit.

[c33] 33. The system of claim 32, wherein each phase shift circuit shifts the input signal between 0 and 120 degrees as represented by the phase shift circuit output signal.

[c34] 34. The system of claim 26, further comprising the virtual flaw map derived from the group consisting of a model and premeasured flaws.

[c35] 35. The system of claim 26, wherein the nondestructive test instrument and a nondestructive test probe are based on eddy current technology.

[c36] 36. The system of claim 26, further comprising a test probe selected from the group consisting of a single element probe, a dual element probe and a triple element probe.